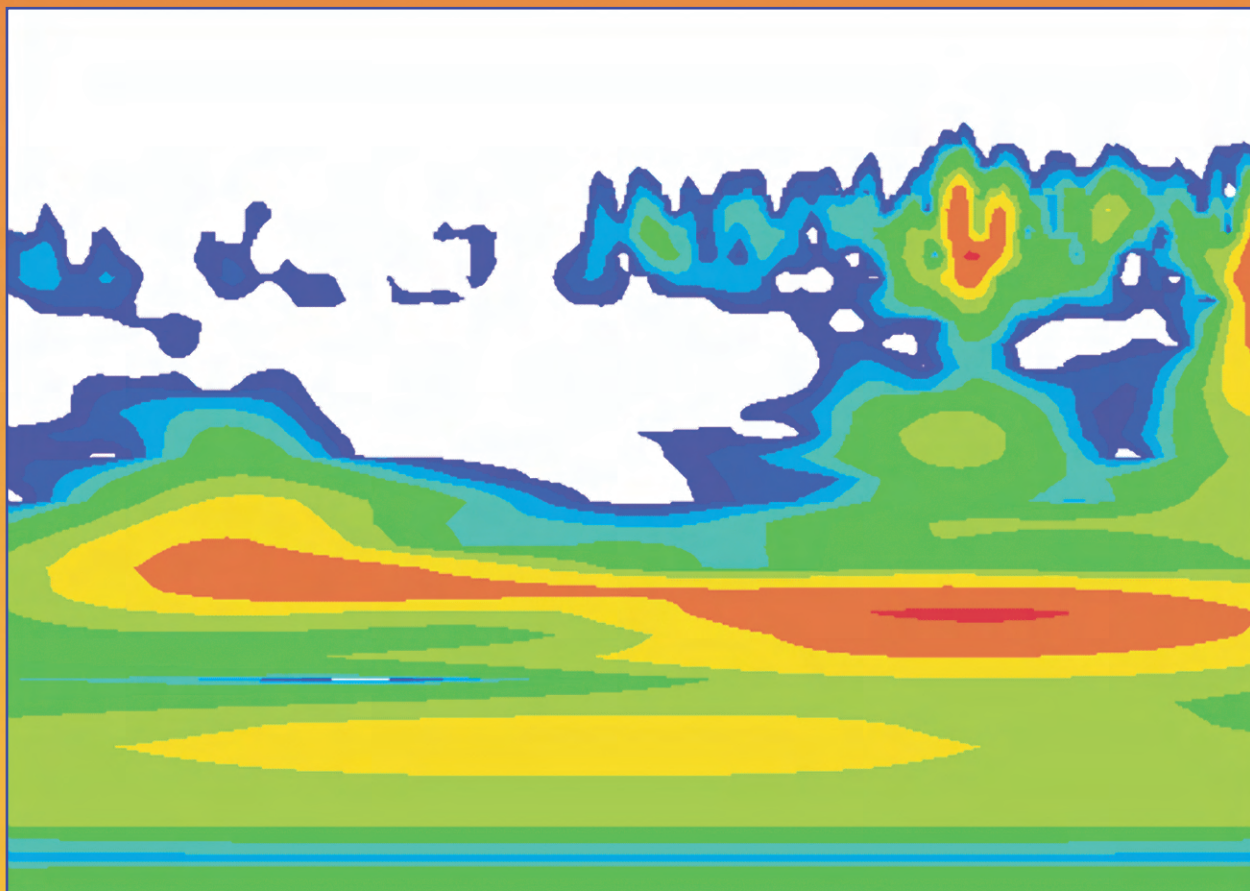


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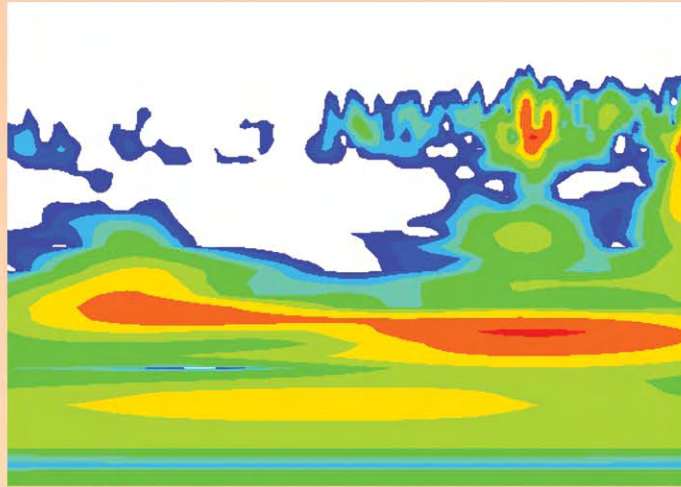


September/October 2003

■ Risk Management ■ LANSCE ■ First beam at DARHT-II ■
■ DANCE ■ PBX 9501 ■

Weapons Science and Engineering at Los Alamos National Laboratory

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- About the cover: Data from the Dual-Axis Radiographic Hydrotest Facility will play a crucial role in stockpile certification. Commissioning of the second axis is in progress: this graphic displays a frequency analysis of beam motion in one experiment during the first commissioning phase, a demonstration that the technology could produce and accelerate a beam of electrons.
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Point of View

Beverly Ramsey

Division Leader

Risk Reduction and Environmental Stewardship

What does risk management mean to weapons science and engineering?

One of the greatest impediments to increasing Los Alamos National Laboratory's environmental business efficiency and to decreasing operational and business risks is what we call the "compliance conundrum." Because of the mechanisms that regulators use as their primary enforcement tools, we continually spend resources to detect lesser and lesser amounts of chemicals or radionuclides in effluents, emissions, and wastes as well as in all environmental media of the LANL reservation and surrounding areas. This results in a continuous action set that chases, measures, and continues to chase or monitor these contaminants (sometimes even if they are indigenous to our geology or common to all northern New Mexico industries and businesses).

The problem with this approach is that it does not focus resources on the actual risks that are posed to the public or the environment; instead, it focuses on concentrations of a myriad of chemicals and radionuclides at numerous "points of compliance." (A point of compliance can be a well, a stream gauging station, or a point downstream of any solid waste management unit or contaminated site.)

This compliance conundrum increasingly demands resources beyond those necessary to ensure LANL's compliance with public health and environmental regulations and standards. This is particularly true of corrective actions related to operations spills, RCRA (Resource Conservation and Recovery Act), or state orders. We often find ourselves attempting to prove that the non-detect is a non-detect and that very low levels of some chemicals or radionuclides are artifacts of sampling, analysis interference, or other problems.

Compliance is not optional. However, resources must be allocated to invest in activities that result in

reducing risks from LANL operations to the public and environmental systems. Without substantial annual increases in our environmental-monitoring budgets, it is increasingly important that we make wise investments that contribute to decision-making and implementing activities that reduce risks.

So, what is the high ground we strive for? Our answer is the deliberate, continual assessment and communication of risk and risk reduction associated with ongoing and historical activities, including waste disposal, conducted at the site. Or to modify a political slogan, *"It's about the risk, people!"*

RRES Division leads an effort that is supported by the weapons science and engineering divisions to

**change the paradigm
from the compliance conundrum
to risk management & reduction**

change the paradigm from the compliance conundrum to risk management/reduction. We believe that by doing so we can achieve not only compliance (a requirement, but only the first rung on the operations excellence ladder) but also a reduction in the otherwise steadily increasing dollars required to monitor and surveil LANL operations.

What does the risk management paradigm mean for our weapons activities?

- Reduced number of waste streams, especially those that require very expensive disposition such as mixed transuranic and mixed low-level waste.
- Increased pollution-prevention initiatives such as sustainable building design, where waste-stream management is part of facility

Continued on page 23

First Beam at DARHT-II

The Dual-Axis Radiographic Hydrotest (DARHT) Facility is the nation's first test facility that can produce three-dimensional, time-resolved data about many complex, dynamic aspects of a nuclear weapon pit during its implosion phase. DARHT's dual-axis multiple-exposure radiographs of nonnuclear mockups of weapons systems will play a crucial role in stockpile certification. Moreover, DARHT will provide the capabilities for dynamic experiments investigating shock physics, high-velocity impacts, materials science, high-explosives science, and industrial applications.

The 1st axis has provided data since 2000, and commissioning of the 2nd axis (DARHT-II) began in 2002. DARHT-II will provide up to four short (<150 ns) radiation pulses for flash radiography of high-explosive-driven implosion experiments. To accomplish this, the DARHT-II linear induction accelerator will produce a 2-kA electron beam with 18-MeV kinetic energy, constant to within $\pm 0.5\%$ for 2 μ s. A fast kicker will cleave four short pulses out of the 2- μ s flattop, with the bulk of the beam diverted into a dump. The short pulses will then be transported to the final-focus magnet and focused onto a tantalum target for conversion to bremsstrahlung pulses for radiography.

Commissioning of DARHT-II is proceeding in three phases. The first phase was a demonstration that the DARHT-II technology could produce and accelerate a beam of electrons. These tests were accomplished at reduced parameters to minimize risk

of damage to this new accelerator. Table 1 shows the parameters for these experiments compared with the final parameters expected when all phases of commissioning are completed.

Table 1: DARHT-II Parameters

	Phase 1 Experiments	Final Parameters
Beam Current	1.2–1.3 kA	2.0 kA
Pulse Length	0.5–1.2 μ s (FWHM)*	2.0 μ s (flattop)
Diode	3.0 MeV	3.2 MeV
8 Injector Cells	1.2 MeV	1.4 MeV
Installed Standard Cells	64	70
Active Standard Cells	61–62	70
Exit Energy	12.5–12.7 MeV	18 MeV

* Full-width half-maximum

Accelerator

The 88-stage Marx generator that powers the injector diode for DARHT-II will produce a 3.2-MeV output pulse that is flat for 2 μ s. The rise time of this pulse at the diode is ~ 500 ns, but to minimize risk of damage in these initial experiments, the Marx generator was configured to produce a shorter, 1.2- μ s FWHM pulse, which was even further shortened on most shots with a diverter switch.

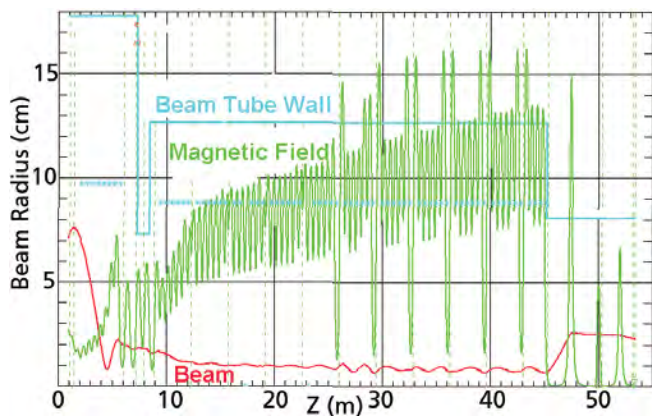
After leaving the diode, the 3.0-MeV beam was accelerated by eight large-bore (36-cm-diameter beam tube) induction cells to 4.2 MeV. The beam next enters a special transport zone designed to scrape off the long-rise-time, off-energy beam head. For these first experiments, this beam-head cleanup

zone (BCUZ) was configured to pass the entire beam head, and the timing of the accelerator was set to accelerate the entire beam, including the off-energy beam head. The magnetic tune through the BCUZ compressed the beam to the smaller radius needed to match into the main accelerator.

The main accelerator consisted of 64 smaller-bore (25.4-cm-diameter beam tube) “standard” induction cells for phase one experiments. Two or three of these were inactive. The magnetic tune through the main accelerator gradually increased to a field of more than 1 kG on axis to suppress the beam-break-up (BBU) instability.

The magnetic tune for these experiments was designed using two beam dynamics codes. First, the TRAK electron-gun design ray-tracing code was used to establish initial conditions at the anode (initial radius, divergence, emittance) for the XTR envelope code at the operating A-K potential of the diode. Then the tune was developed for the energy flattop of the beam using the accelerating voltages that were expected to be applied to the gaps. Finally, the lossless transport of the off-energy beam head was computationally verified using XTR simulations in steps of 100-kV A-K potential, with initial conditions from individual TRAK simulations.

Diagnostics



DARHT-II tune for commissioning experiments.

DARHT-II is heavily instrumented with beam and pulsed-power diagnostics. In addition to diagnostics that monitor performance of the Marx generator, capacitive dividers in the diode vacuum measure the actual diode voltage waveform. Each

induction cell has a resistive divider to measure the voltage waveform delivered by the pulse-forming network. There are beam position monitors (BPMs) at the entrance to each block of cells, as well as three more in the diode-anode region, one at the exit of the injector cells, two in the BCUZ, and one just before the imaging target. The BPMs also measure the beam current passing each position. Streak and framing cameras produce images of beam-generated Cerenkov and optical transition radiation (OTR) light from targets inserted in the beam line. Finally, a magnetic spectrometer is used to measure the beam kinetic energy.

DARHT-II is a collaborative effort of Los Alamos, Lawrence Livermore, and Lawrence Berkeley National Laboratories operated by the University of California, with support provided by Bechtel Nevada and Mission Research.

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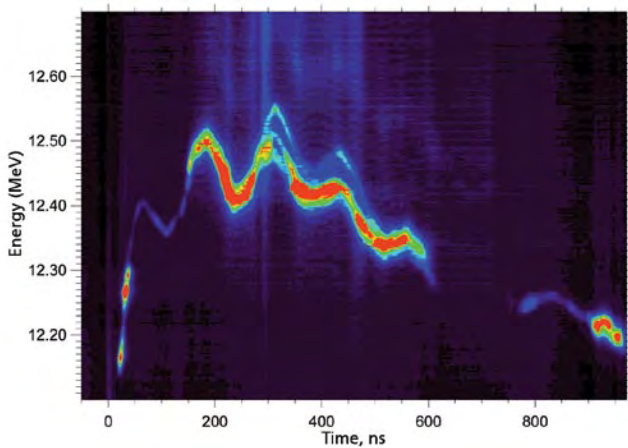
Mission Research: T. Hughes and C. Mostrom

Results

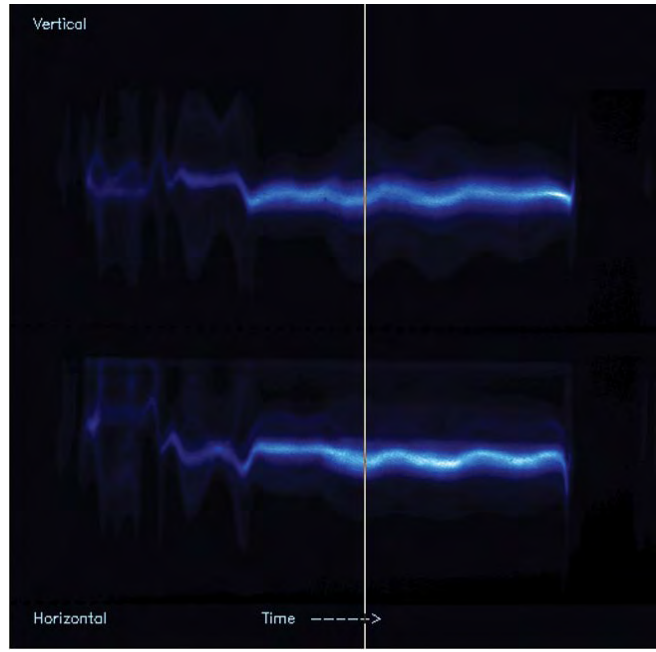
Results indicated that the eight injector cells accelerated the beam without loss of current within the $\sim 2\%$ uncertainty of the measurement. Some of the beam head was then lost in the BCUZ throat, and very little further loss occurred as the beam was accelerated through the remaining 64 accelerator cells. These results verify that the magnetic tune indeed realized the design goal of negligible off-energy beam-head loss in the cells.

A striking feature of this diode is the 7.8-MHz oscillation on the main pulse, which is about $\pm 1.5\%$ of the voltage at the peak. This is an LC oscillation caused by the capacitances and inductances of the injector structure. The fully accelerated beam kinetic energy was measured with the magnetic spectrometer to be >12.2 MeV for 500 ns, with a peak energy >12.5 MeV. The 7.8-MHz oscillation is clearly evident on this sensitive scale, although it amounts to only $\pm 0.4\%$ of the accelerated beam energy. A resistive damping circuit to quench this oscillation is now being tested and could be installed if necessary.

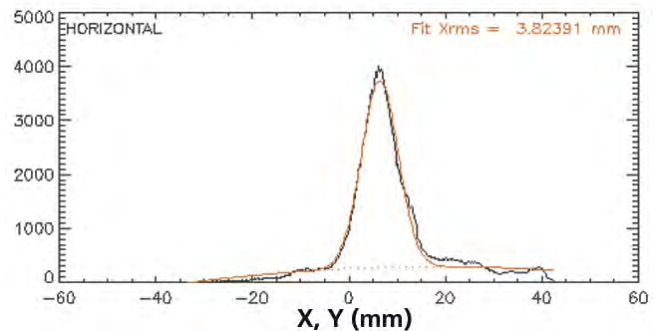
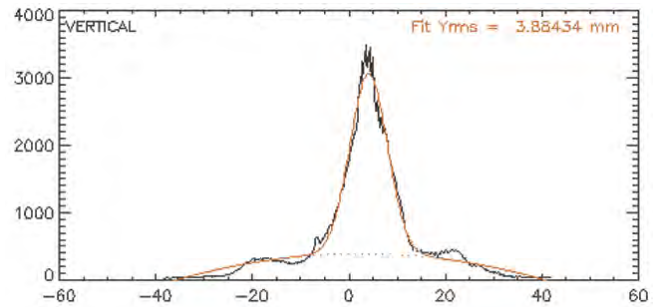
This oscillation in the diode causes an oscillation of the beam position as a result of an accidental magnetic dipole in the diode region, which is clearly evident at the first BPM that is located at the diode exit. This initial motion is modified by the magnetic transport but does not grow in amplitude through the accelerator. Although DAR-



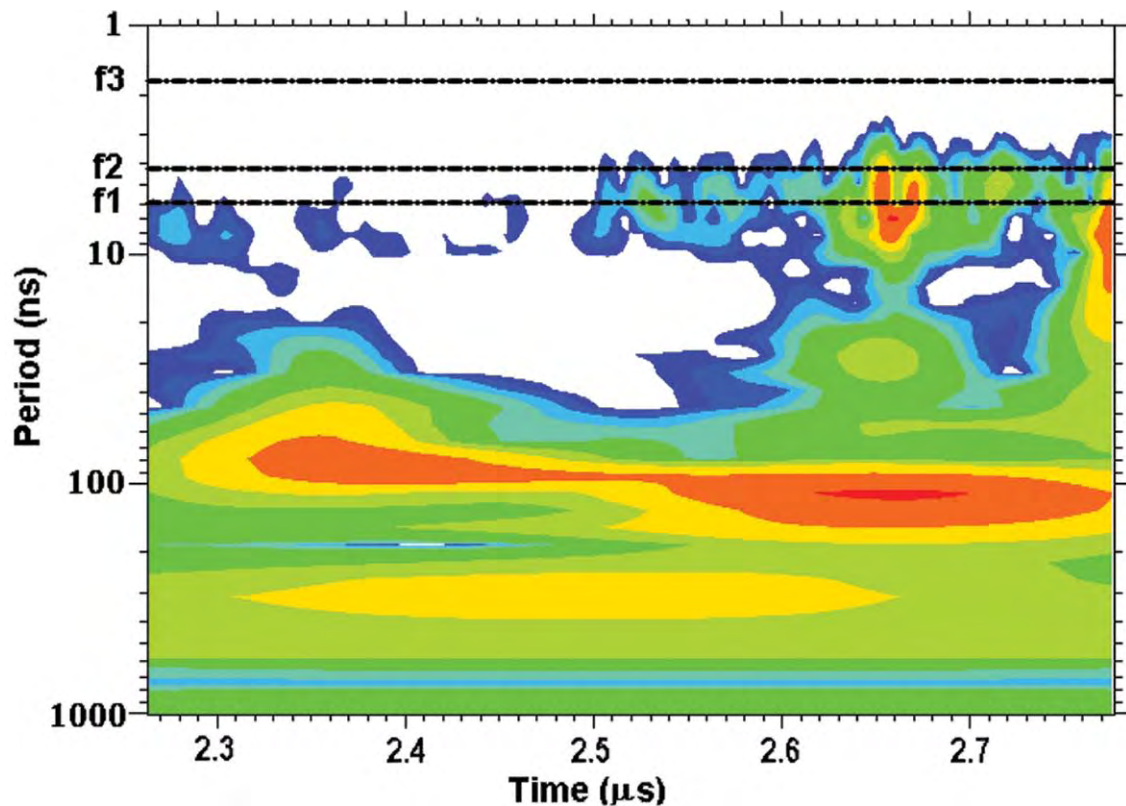
Streak camera readout of electron energy during a pulse.



Anamorphic streak images of ~ 1.5 -cm-diameter beam. Time runs left to right. Top: Projection in vertical plane (anamorphically compressed in horizontal direction). Bottom: Projection in horizontal plane (anamorphically compressed in vertical direction).



Projections at lineout time shown in the graphic at the top of this column. A fitted model consisting of a Gaussian core plus quadratic halo is over-plotted. Amplitude units are raw CCD counts.



Frequency analysis of motion of the beam centroid with magnetic field reduced by factor of 5. BBU frequencies for the accelerator cells are $f_1=169$ MHz, $f_2=236$ MHz, and $f_3=572$ MHz.

HT-II is equipped with steering dipoles throughout, they were neither needed nor used for these experiments.

Anamorphic streak images of the beam after the accelerator exit showed that the elliptical beam profile had a Gaussian-like core surrounded by a halo that includes <20% of the total current. The beam centroid motion seen in the streak images had excellent correlation with the beam position measured with a BPM 40 cm upstream of the imaging target. Using a focusing-magnet scan technique, the emittance of the Gaussian core of the beam was estimated to $<1000 \pi$ -mm-mr, which is the goal for the accelerator.

We completed this first round of commissioning with tests of resistance BBU instability, which is suppressed by the magnetic guide field. No evidence of BBU growth was seen until the magnetic field strength was reduced by a factor of 5 through-

out the 64 standard cells, at which point BBU became evident late in the pulse. Since the BBU growth exponentiates with current and the number of cells, this result implies that this magnetic tune will be more than adequate to suppress BBU with the final 2-kA current and full complement of 70 cells.

The next and final commissioning phases will demonstrate the operation of the BCUZ, multiple- beam pulse production by the kicker, and the production of multiple radiographic-quality bremsstrahlung pulses. We anticipate that commissioning will be complete in late 2005. *

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Direct Numerical Simulations of PBX 9501

Modeling composites with complex microstructures has been a continuing challenge in the field of mechanics of materials modeling. Here, we are concerned with two-phase composites consisting of grains of high explosive bonded together by an elastically softer matrix material.

The microstructure of such composites is complex because the grains are characterized by a broad size distribution and irregular positioning. Numerical homogenization of the microstructure is often necessary to create computationally fast and efficient models. Homogenized models, however, cannot directly predict localization phenomena resulting in nonuniformities in stress, strain, temperature, and damage fields.

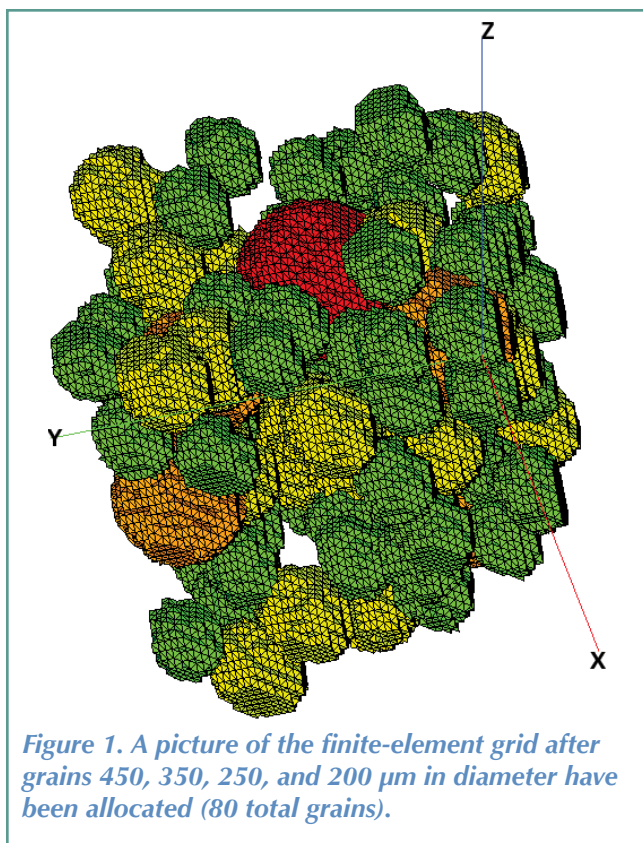
A complex microstructure can give rise to highly fluctuating fields, even under simple loading. In a two-phase composite, consisting of grains in contact with each other and surrounded by a softer matrix, the elastically stiffer grains can carry more load than can the matrix through a process known as stress bridging. Further, the composite microstructure can lead to stress isolation of grains for those grains that are excluded from the bridging path. All of these scenarios lead to complex stress distributions at the length-scales of the grains. For an explosive, knowledge of the phenomena occurring at those length scales is critical.

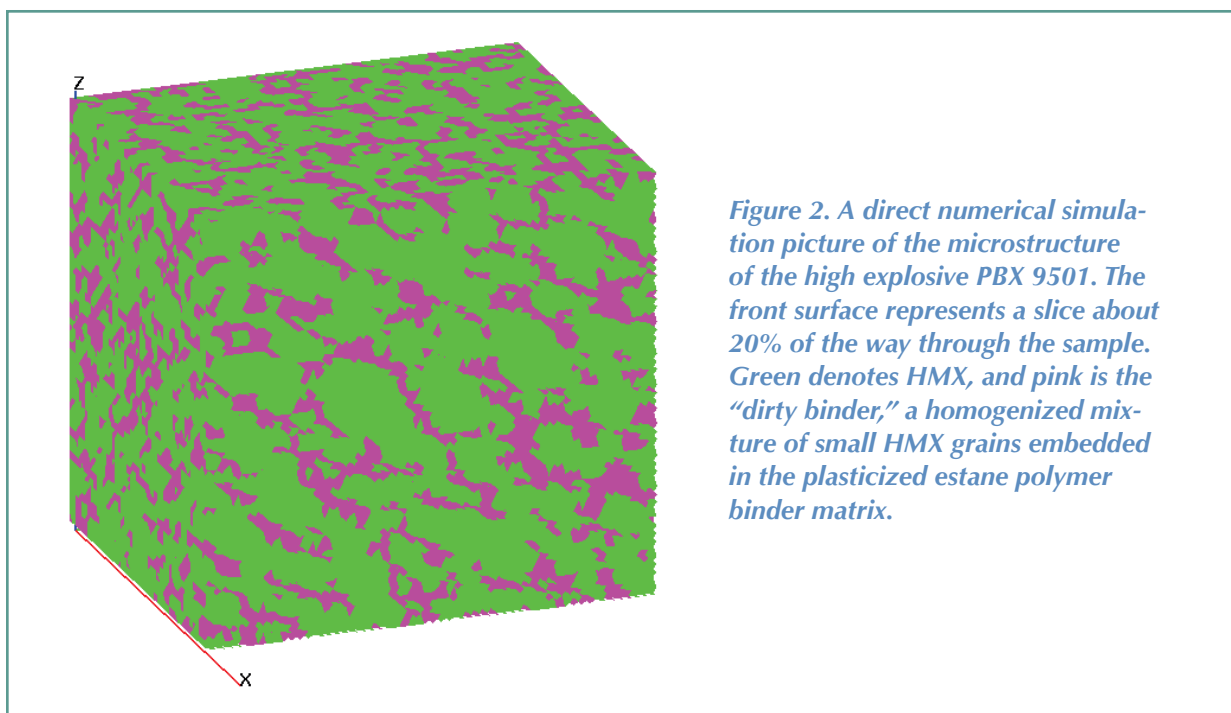
We have conducted direct numerical simulations (DNSs) on the high-explosive composite PBX 9501 using finite-element analysis (FEA). As much of the microstructure is explicitly gridded as is numerically tractable; this resolution allows us to observe some of the localization effects. PBX 9501 has a very complicated microstructure, consisting of high melting explosive (HMX) grains (95 wt%) embedded in a plasticized estane polymer matrix (5 wt%). The HMX grains range in size from several hundred micrometers to sub-micrometer diameters.

To conduct DNSs on PBX 9501, two key factors must be addressed: first, a finite-element grid (see Figure 1) must be created that captures as much of the microstructure as possible without being too complex to simulate in a reasonable amount of time, and second, the constitutive models must capture the necessary physics while also being numerically efficient.

For an explosive, our knowledge of the phenomena occurring at the micrometer length scales of individual grains is critical

In 1997, a study in DX Division by Skidmore, Phillips, Son, and Asay reported a study of HMX grain sizes in PBX 9501. They removed the plasticized





estane binder with a solvent and measured the particle size distribution by laser diffraction. That study provides us with an experimentally derived grain size distribution.

In our DNSs we approximate their continuous distribution with seven discrete grain diameters (450, 350, 250, 200, 150, 100, and 50 μm), effectively accounting for grains down to a 25- μm diameter. Assuming one 450- μm grain, we used the discrete distribution to calculate the approximate number of other grains, leading us to a total of approximately 1,600 grains.

We can also infer from the distribution that 80 vol% of the HMX resides in grains with a diameter of 25 μm or larger, which implies that the finite-element-gridded HMX grains should account for 75 vol% of the PBX 9501. The remaining 25 vol% is modeled as a homogenized mixture of small HMX grains embedded in the binder matrix. This mixture, represented by a model that we developed (see Figure 2), will be referred to as the “dirty binder.” The dirty binder contains approximately 75% HMX and 25% binder matrix (note that it is a coincidence that both of these mixtures are 75/25).

The finite-element grid was generated using La-GriT, the Los Alamos Grid Toolbox, on a regular tetrahedral mesh of approximately one million ele-

ments. The smallest grain was represented by about ten finite elements. The center of the largest grain was nearly randomly positioned within the simulation sample box but was restricted to be at least 90% of the grain radius distant from the sides of the sample. The full grain was then constructed about this location by specifying all of the finite elements that share a node with the initial element as being part of this HMX grain. Successive shells are specified as being HMX in this way until the appropriate volume is attained.

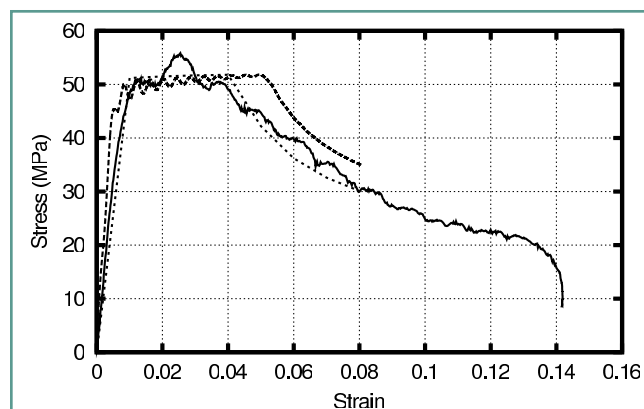
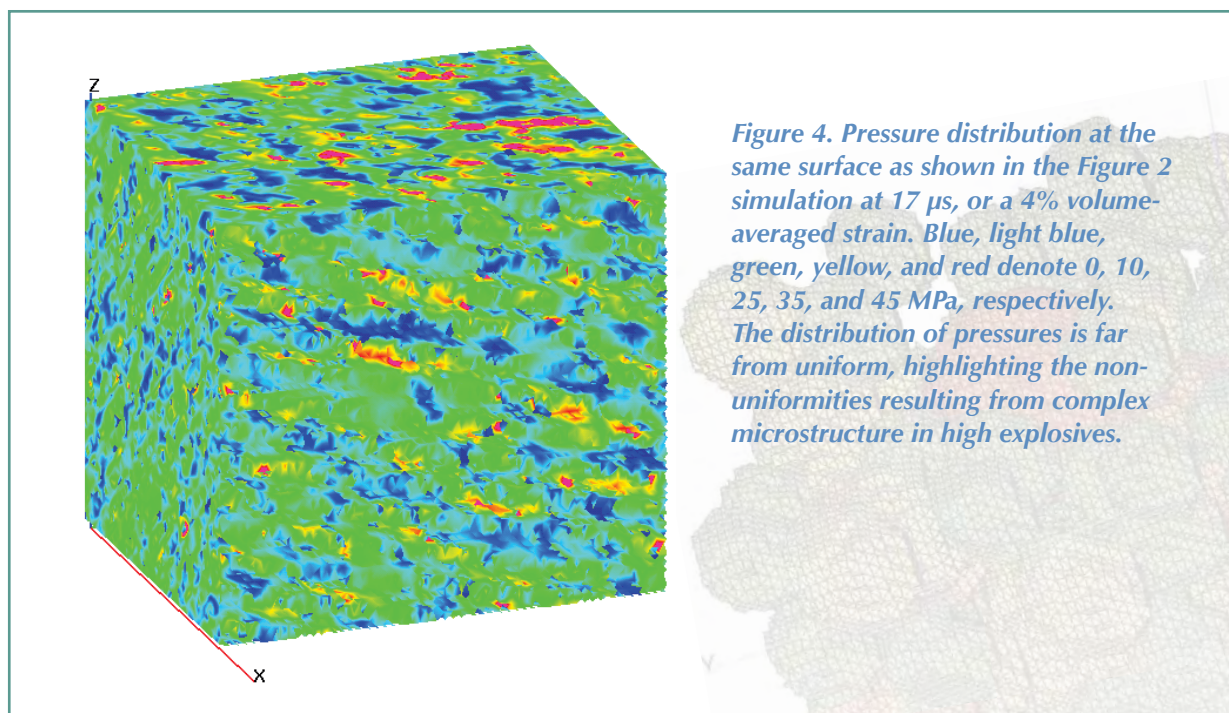


Figure 3. A fit of model stress-strain curves to experiment. Experimental data are represented by the solid line, the direct numerical simulation is the dashed line, and the method of cells simulation is the dots.



The center of the next largest grain was then randomly placed in the finite-element mesh, this time with the restriction that its center be 81% of the grain radius from the sides of the sample and the sides of the large grain. The remaining grains are similarly allocated within the mesh. A picture of the grid after the last 200- μ m-diameter grain has been positioned is shown in Figure 1. A picture of the final microstructure model is provided in Figure 2. The front surface represents a slice that is approximately 20% of the way through the sample. Individual grains can be observed, as can percolating paths of dirty binder. This appears to be a much better representation of PBX 9501 than has previously been seen in the modeling literature. Parameters for our model come from three sources: values calculated directly from experiments (elastic moduli, densities, etc.), values fit to experiments on constituents (relaxation spectra of the binder), and values fit to experiments on the composite (some parameters of the cracking model and yield stress). The latter two were determined by our method of cells (MOC)-dirty binder hybrid model fit to those experiments. The resulting stress-strain fit is shown in Figure 3.

The DNSs, using the above constitutive theories and finite-element grid, were carried out using the

FEA code EPIC. We modeled a load similar to a split Hopkinson pressure bar experiment, specifically uniaxial stress with an applied strain rate of 2000 s^{-1} , by applying velocity boundary conditions on the top and bottom nodes of the sample box. A simulation to a strain of 8% took about 4 days on a single-processor alpha workstation. In the future, and with the arrival of a parallel version of EPIC, we plan to simulate larger, more representative samples of PBX 9501 under more complicated loading conditions.

The purpose of the results is twofold: to show agreement with experiment to validate the above load-simulation procedure and to analyze the DNS data for information elucidating qualitative or quantitative information about what is happening in the composite as it is loaded. This information can then be used as a tool for general understanding of explosives and as a guide for other meso- and macro-models that might be missing important properties of the composite.

The DNSs agree satisfactorily with the experimental stress-strain curve, as shown in Figure 3. The agreement is also close to the MOC simulation described above that produced the parameters used in the simulation.

Other information gleaned from these simulations is more interesting. In the course of a simulation, we observed stress bridging between HMX crystals, as one might expect. We also observed that the distribution of most quantities, including stress, pressure, and crack size, varied considerably from grain to grain and within grains. Figure 4 shows the distribution of pressures at the same surface shown in Figure 2, at a volumetric strain of 4%.

As can be seen, the distribution is far from uniform. In fact, the volume average of the pressure is about 17 MPa (where light blue borders on green in Figure 4) and the pressures are seen to reach easily three times that in some grains. Further, there are regions that are predicted to be in tension (very dark blue). None of these results would be observed with a homogenized model of the composite. As mentioned before, similar distributions occur for other observables.

Figure 5 shows a histogram of pressure versus the number of elements at that pressure for different times in the simulation. We were surprised that the negative pressures reached such high values, but for each negative pressure, there are an order of magnitude more elements at the positive value of

that same pressure. The distribution shows that all values of pressure are present at any given time out to a value of approximately three times the volumetric average. This is interesting from the point of view that no matter what the volumetric average of the pressure is, there are always grains at low pressure. This might be an important observation with application to the chemistry of detonation.

Many processes in the chemistry of detonation are thought to be affected by high pressure. Despite this view, there is no evidence present in time-to-ignition data, ranging from thermal explosion to detonation, that indicates a kinetic effect associated with a pressure buildup. The lack of a pressure dependence observed in these experiments, coupled with the persistence of low-pressure regions observed in these simulations, offers the possible explanation that the low-pressure regions might play an important role in the initiation of high explosives. *

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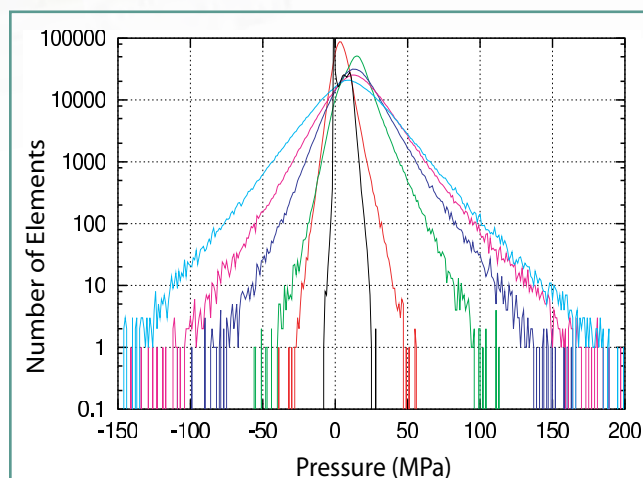


Figure 5. Histogram of pressure versus the number of elements at that pressure at different times in the direct numerical simulation. Black, red, green, blue, purple, and turquoise are at 0.1, 1, 2, 5, 10, and 25 μ s, respectively (0.1 means zero elements). Here, the tops of the histogram are connected with a line for ease of reading. Note that independent of the volumetric average pressure, there are always grains of high explosive at low pressure.

The authors thank William Blumenthal (MST-8) for his work and advice on experimental matters. The authors also thank Laura Smilowitz (C-PCS) and Bryan Henson (C-PCS) for their discussions about chemistry in PBX 9501. We also gratefully acknowledge discussions with J. N. Johnson, P. J. Maudlin, C. Liu, D. Idar, and F. Addessio. The authors gratefully acknowledge financial support for this work from the Joint DoD/DOE Munitions Technology Development Program and from the Laboratory's HE Science Program.

Stockpile Stewardship Contributions by LANSCE in 2002

Overview

The Los Alamos Neutron Science Center (LANSCE) is a unique facility in the national laboratory complex. LANSCE produces the highest-power medium-energy proton beam in the US. The protons are used to radiograph dynamic events or to produce intense pulses of spallation neutrons. The versatility of LANSCE allows scientists to perform experiments in fundamental physics, materials science, nuclear science, and shock physics using proton or neutron irradiation, neutron scattering, and neutron resonance spectroscopy.

The data that result from
LANSCE experiments have a
direct impact on understanding
the physics and materials
behavior in a nuclear device

During operations in 2002, LANSCE operated reliably for the National User Program. The user facilities at the Manuel Lujan Center and the Weapons Neutron Research (WNR) facility hosted 224 experiments serving 782 user visits. The proton radiography (pRad) program at LANSCE conducted a very successful campaign that formed the foundation for the most successful year in the history of that program. The LANSCE accelerator once again delivered 100% beam availability for a total of 42 dynamic experiments. Since the inception of proton radiography, the number of pRad experiments has reached 156.

Operated under the direction of Los Alamos for NNSA, LANSCE provides proton and neutron beams for state-of-the-art experiments in three broad areas of research: nuclear science, proton radiography, and materials science. Data taken at LANSCE by the three weapons laboratories,

Los Alamos, Livermore, and Sandia, directly impact our understanding of the physics and materials behavior in a nuclear device. These data have many uses. For example, some are incorporated in the Advanced Simulation and Computing (ASCI) codes for device design. Others are used in analyzing data from previous nuclear tests for the Stockpile Stewardship Program. Some of these data are also used for lifetime extension programs and in significant finding investigations. Researchers at LANSCE made significant accomplishments during the 2002 run cycle in all three areas of research.

Nuclear Science

Efforts in stockpile stewardship nuclear science at LANSCE made significant progress over the past year. Major initiatives in this area involved three unique, large detector systems needed to detect products from neutron reactions: the Germanium Array for Neutron-Induced Excitations (GEANIE), the Detector for Advanced Neutron Capture Experiments (DANCE), and the Fast neutron-Induced Gamma Ray Observer (FIGARO). In addition, a new capability to provide neutron radiography as a stockpile surveillance tool is under development.

Radiochemical (radchem) diagnostics play an important role in understanding the detonation of a nuclear device. One method is to measure the amount of specific isotopes produced by the fission process. For example, neutrons impacting the fissionable material can be captured (n,gamma) or can produce secondary neutrons (n,2n) to generate isotopes of the parent nucleus. The ratios of the probability for these reactions relative to the fission probability are well known. Thus, measurement of the amount of ^{238}Pu or ^{240}Pu can indicate the amount of fission that occurred.

Determination of the fusion yield is more difficult because the isotopes produced by neutron inter-

actions with the fusion fuels are not readily discernable. Consequently, some elements or isotopes can be inserted as radchem detectors at various locations in a nuclear device. During detonation,

The following contacts can provide more information about research at LANSCE:

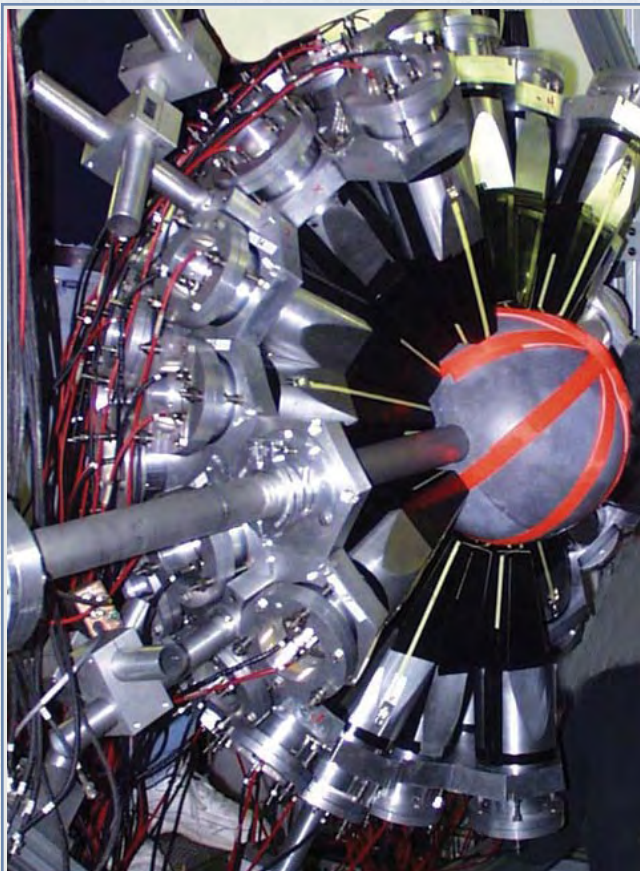
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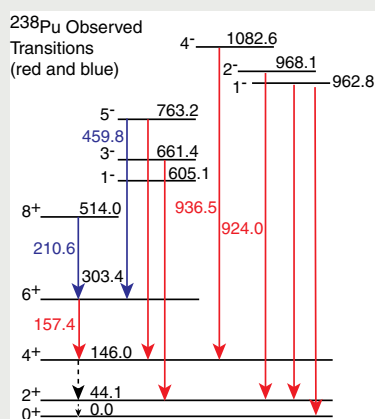


these detectors are subjected to a short and intense flux of fission and possibly fusion neutrons. After the detonation, the radchem detectors and their long-lived activation products are retrieved from the underground explosion site and subsequently analyzed. Many of the reactions for these radchem isotopes have a lower limit, or threshold, for the neutron energy. Neutrons below this threshold do not produce the reaction. By placing several elements with different thresholds into the device, we can infer the energy distribution of the neutrons by measuring the amount of the reaction products. Computational models are then used to match observed amount of isotopes to determine the energy distribution of the neutrons and to provide the fission yield value.

Although many of these radioactive products have short half-lives, their lifetimes are long on the timescale of the explosion. Thus, the buildup and destruction of the reaction products can impact the performance and the diagnosis of the weapon. Accurate measurement of the neutron reaction probabilities, i.e., the neutron cross sections, at LANSCE allows designers running the weapons codes to improve predictions of the radioactive products produced by the explosion.

DANCE is designed to measure neutron-capture cross sections on radioactive targets with masses as low as 0.5 mg. During the 2002 run cycle at LANSCE, we made the first measurements of the neutron-capture cross section of ^{234}U with DANCE. With the intense neutron flux available at the Lujan Center, DANCE is presently the most sensitive instrument for neutron capture experiments in the world.

Fission is the dominant energy-release mechanism in a nuclear device. Understanding the fission process and the products of the process enables accurate modeling of device performance. In addition, understanding the manner in which the fission energy is partitioned into fission products, gamma rays, x-rays, and neutrons improves the modeling of energy deposition profiles in weapons calculations. New measurements of the energy spectra of the prompt neutrons emitted and of the prompt gamma-ray energy spectra are in progress using GEANIE, a large gamma-ray detector array at the



A Los Alamos/Livermore collaboration is now studying the use of iridium and europium (and other isotopes) as radchem detectors. The collaboration has developed a technique for determining activation cross sections over a wide incident-neutron energy range using the GEANIE detector. These activation cross sections, which are difficult to obtain by other means, are needed to better understand the detonation of nuclear devices and in other applications for which neutron-fluence measurements are required. For example, data obtained with GEANIE extend beyond the range of neutron energies produced in a nuclear device, and, consequently the data have application in systems for transmutation of nuclear waste or in other high-energy systems that use neutrons.

Q machine was made available to the users in the secure environment in August 2002. This machine was used to complete a Los Alamos ASCI milestone calculation for NNSA in December 2002 for which the Shavano Code Project Team recently won the Laboratory's Distinguished Performance Award.

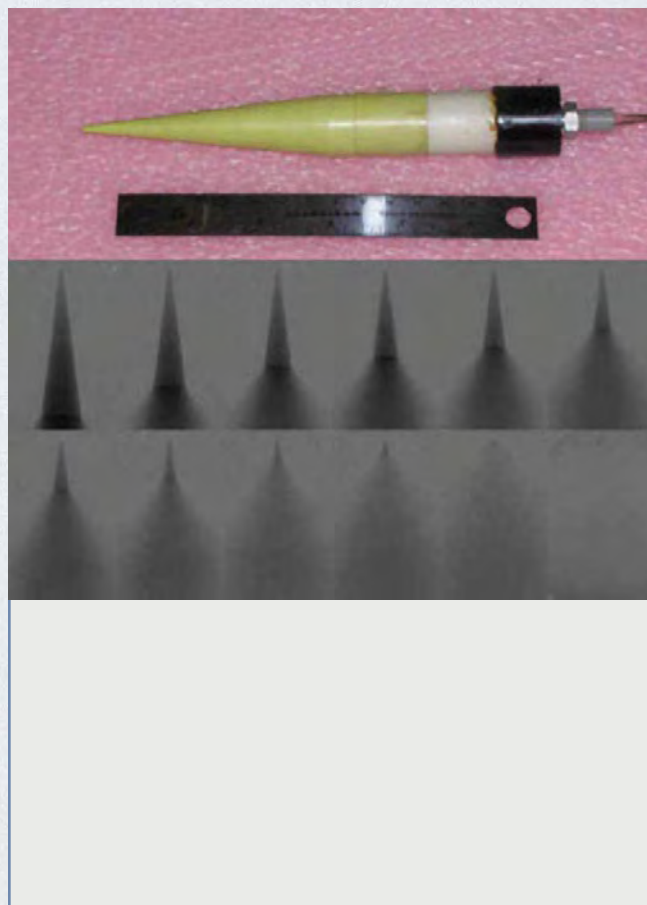
12

A team from LANSCE-3 and P-23 assembled a neutron detector and placed it in the computer room to measure the neutron flux in the computer room environment. To address the system response, a second team consisting of staff from LANSCE-3 and Hewlett-Packard began testing a single module of the Q machine at the WNR neutron source. The WNR neutron source has the unique feature that its neutron spectrum closely matches the spectrum of neutrons produced by cosmic rays interacting with the atmosphere. The intensity of the WNR neutron beam is, however, approximately 10^8 times more intense. The results of the tests strongly indicate that a large part of the failure rate is due to single-event upsets caused by cosmic rays. These measurements solved the mystery of the Q machine failure rate and suggest possible mitigation strategies.

Finally, researchers in P-23, using the LANSCE beam to produce short bursts of neutrons, extended the application of a new measurement technique that allows a determination of the temperature of material behind a shock front. During the last run cycle, the Neutron Resonance Spectroscopy (NRS) team performed four dynamic experiments to measure the temperature in an explosively formed copper jet. The experiments were aimed at testing models of metals under high strains and strain rates. In a second experimental thrust, the first in a series of NRS experiments was performed to measure the temperature behind the burn front of detonating high explosive (HE) doped with a neutron-absorbing material. The test series uses samples made by a new method that reduces dopant granularity within the samples. Present theoretical uncertainties in the temperature are quite large, and a precise measurement will greatly improve the characterization of the equation of state of detonating HE.

Proton Radiography

Historically, the nuclear weapons program has utilized pulses of x-rays to take pictures of device components as they were imploded by HE, i.e., dynamically. This capability has recently been improved with the construction of the Dual-Axis Ra-



diographic Hydrodynamic Test (DARHT) Facility at Los Alamos. DARHT has the capability to see through dense, imploding devices using an intense pulse of high-energy x-rays. Currently, DARHT has the ability to take a single “snapshot” of the imploding system.

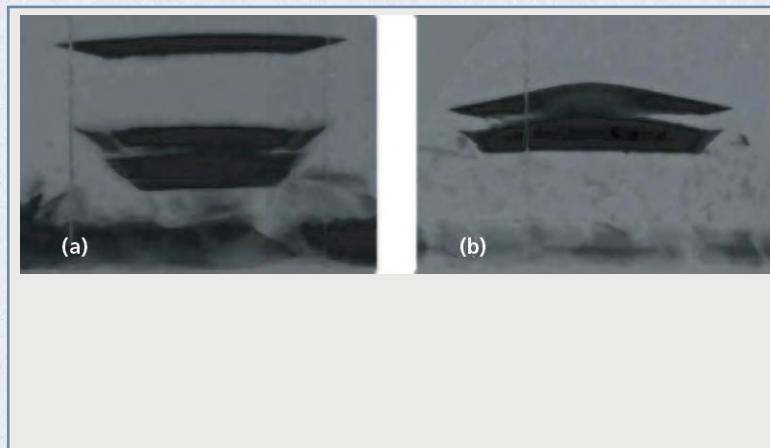
Many of the questions of interest to stockpile stewardship, however, are time-dependent and require images taken at different times in the implosion. By using the multiple pulses of protons available at LANSCE, a sequence of pictures can be produced that shows the contours of dense materials as they implode. Consequently, even though the 800-MeV protons currently provided at LANSCE cannot “see through” as much material as DARHT x-rays can, pRad is an excellent complement to the DARHT capability. The data taken at both the DARHT and pRad facilities are compared to calculations using weapons hydrodynamic codes to validate the algorithms used for weapons design.

The pRad program under group P-25 is investigating weapons-physics issues related to the detonation of HE along with the equation of state (EOS) of the burned HE products, the dynamic failure processes such as spall and shear banding of explosively driven metals, and the hydrodynamics of implosions. This program provides the unique capability of studying the evolution of explosive processes with high spatial and temporal resolution.

In 2002, 42 dynamic pRad experiments—a run-cycle shot record—were performed at LANSCE in support of the weapons-physics efforts at Los Alamos, Sandia, Livermore, and the Atomic Weapons Establishment

(AWE) at Aldermaston, England, bringing the total number of dynamic pRad experiments performed at LANSCE to 156. For these shots, the LANSCE accelerator and beam-delivery complex provided protons with 100% reliability. In addition to these dynamic experiments, beam time was used for detector and concept development and for the radiography of static mockups to determine shot configurations and the design of future experiments.

The 42 pRad shots in 2002 fell into three categories: outside-user experiments, studies of HE burn characteristics, and studies of material failure mechanisms such as spall and shear banding. Two experiments were fired for Sandia to continue investigations on the dynamics of explosively driven voltage bars used for neutron generators. Three experiments were performed with Livermore to study the material-failure characteristics of steel under various shear- and stress-dynamic-loading scenarios. A sixth dynamic experiment was performed with AWE to investigate the bonding strength of a thin lead layer bonded to an aluminum disk.



Of the 42 dynamic experiments, 18 were devoted to the study of HE burn characteristics. Three of these experiments were designed to study the EOS of HE burn products, two measured the width of the HE detonation zone in PBX 9501 and PBX 9502 high explosives, and the remaining experiments were designed to study the characteristics of detonating HE. An experimental series named AFX-221 was performed for the US Air Force to study burn characteristics around objects embedded within HE. Nine dynam-

ic experiments were performed to study the spall-formation process in aluminum, copper, tin, and 316L stainless steel. Two experiments were performed to study the fracture mechanisms of thin cylinders of titanium. A classified experiment involved a configuration con-

taining the largest HE load (~10 lb) ever fired at LANSCE. This experiment is being carefully simulated on computers to provide model data for comparison to the data collected with pRad.

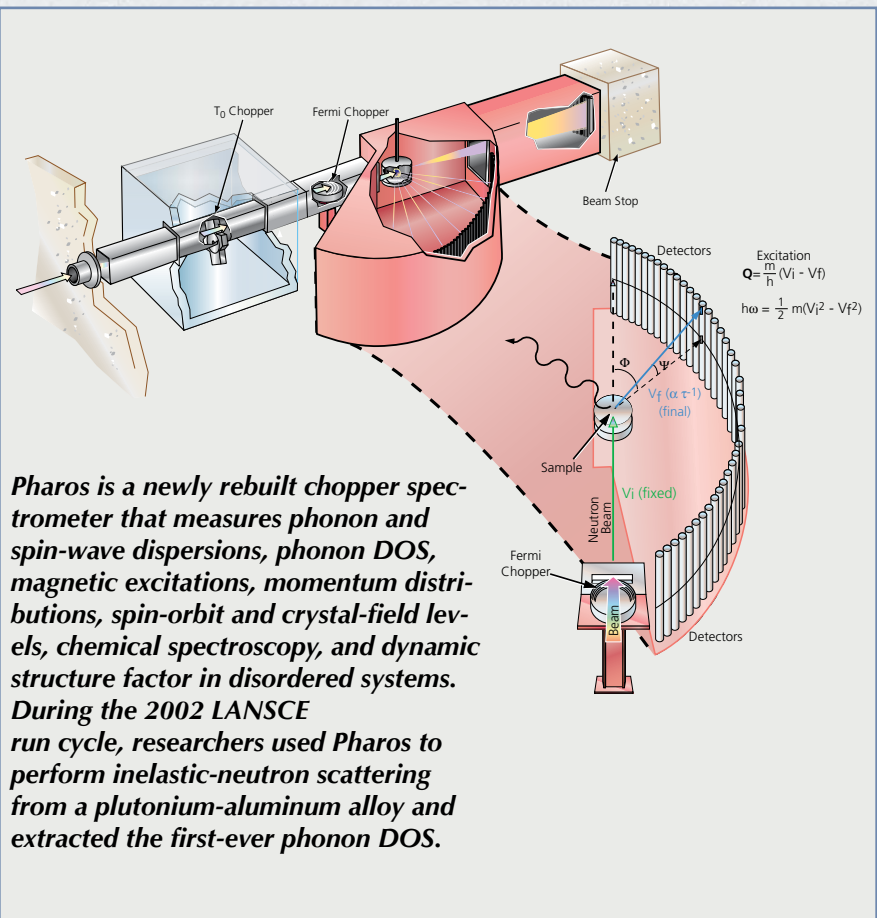
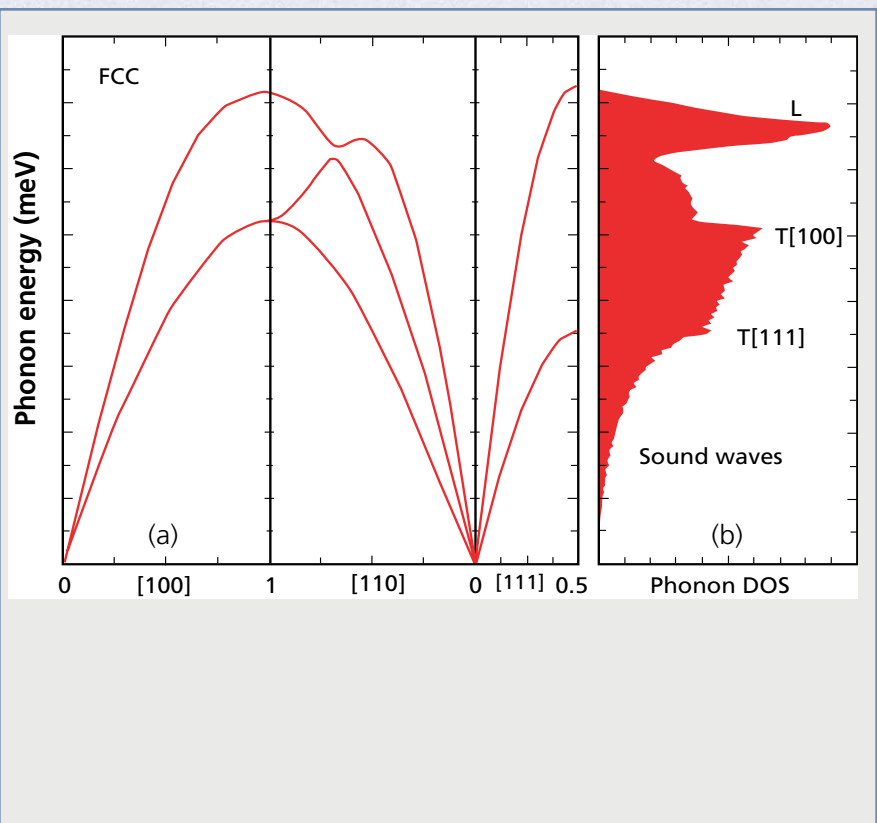
During the 2002 run cycle, LANSCE-1 designed and built a new high-gradient, permanent-magnet microscope, which was successfully tested by the pRad team. The design of this new permanent-magnet-quadrupole (PMQ) microscope system was part of a larger Laboratory-Directed Research and Development project to develop a pRad capability to study phenomena on a 10- μ m scale. The pRad microscope was commissioned in the fall of 2002. This microscope system was designed to improve the radiographic resolution to study the mesoscale properties of dynamic systems. The commissioning effort was very successful in improving the resolution from the 200 μ m achieved with the standard radiography system to 18 μ m.

Weapons Materials Science

Stockpile Stewardship Program research at LANSCE that focuses on weapons materials science takes advantage of the powerful suite of instruments and intense neutron beams available at the Lujan Center. Scientists have made excellent progress on a number of key weapons materials issues in the areas of

- plutonium aging and phase stability,
- EOS of plutonium and other weapons materials with future emphasis on measurements at high pressure and temperature,
- constitutive properties of weapons materials (including plutonium) via microstructure characterization (e.g., crystallographic texture), and
- component lifetime assessment and manufacturing benchmarking provided by measurements of applied and residual strain and other techniques.

The solid-state properties of plutonium are significantly more complicated than those of most other metals. These complex physical properties arise from the role of the 5f electrons in the chemical bonding between atoms. One possible way to verify the accuracy of electronic-structure calculations is through the measurement of the phonon dispersion in the different phases of plutonium. Phonons are the normal modes of atomic vibration on a crystal lattice. The frequency of a particular phonon depends on the wavelength and displacement pattern of the atom's motion



and the forces acting between atoms. These forces arise entirely from the bonding properties and are a stringent test of first-principles electronic-band-structure calculations.

Inelastic-neutron-scattering (INS) measurements from single crystals of plutonium directly give the phonon dispersion. However, single-crystal samples of sufficient size ($\sim 1 \text{ cm}^3$) for this technique are not presently available. From polycrystalline samples, we can obtain the phonon densities of states (DOS), which contains a complete description of the lattice thermodynamics and information about the interatomic forces. We were able to obtain $\sim 35 \text{ g}$ of $\text{Pu}_{0.95}\text{Al}_{0.05}$ enriched to 95% ^{242}Pu (the ^{242}Pu isotope is necessary to reduce absorption). The DOS for $\text{Pu}_{0.95}\text{Al}_{0.05}$ was measured for the first time ever at several temperatures using the Pharos spectrometer at LANSCE. The phonon graph at the top of page 15 shows a schematic of DOS data.

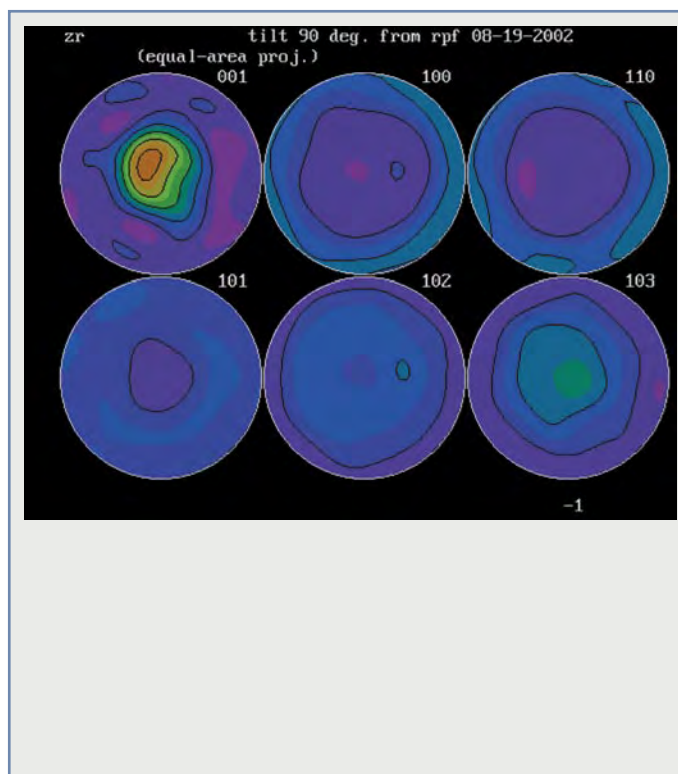
Similarly, a detailed understanding of the stress-induced texture evolution and phase transformations that occur during shock loading of weapons materials is central to understanding and accurately modeling the underlying implosion physics in nuclear weapons. Phase transitions in weapons materials, especially if associated with a large volumetric change, can profoundly affect material states and constitutive, damage, and fracture properties during implosion. For example, during the 2002 run cycle at LANSCE, shock-induced changes in a sample of high-purity zirconium were examined using neutron diffraction with the High-Intensity Powder Diffractometer (HIPD). Zirconium ex-

hibits a subset of the extremely complex dynamics and phase-stability behavior exhibited by materials relevant to stockpile stewardship, to the Stockpile Life Extension Program, and to core elements of the Nuclear Weapons Technology Program. The goals for the zirconium studies were to develop models of the EOS and strengths of weapons ma-

terials and to improve our understanding of the fundamental physics and materials science of nuclear weapons.

The LANSCE 2002 run cycle included many more experiments than have been briefly described in this article. The emphasis here is on those experiments that relate directly to the Stockpile Stewardship Program.

A more comprehensive review of the unclassified research at LANSCE can be found in the *CY2002 LANSCE Activity Report* (LA-



14036-PR). *

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DANCE

Neutron Capture Experiments

DANCE (Detector for Advanced Neutron Capture Experiments) is located on one of the neutron flight paths in the Manuel Lujan Jr. Neutron Scattering Center (Lujan Center). The Lujan Center, a pulsed spallation neutron source equipped with time-of-flight spectrometers for neutron-scattering studies of condensed matter, is at the business end of the LANSCE proton accelerator. DANCE has been developed to address fundamental questions regarding nuclear reactions that occur during nuclear explosions. DANCE offers unique capabilities for using small quantities of radioactive isotopes to study nuclear reactions.

Radchem Detectors

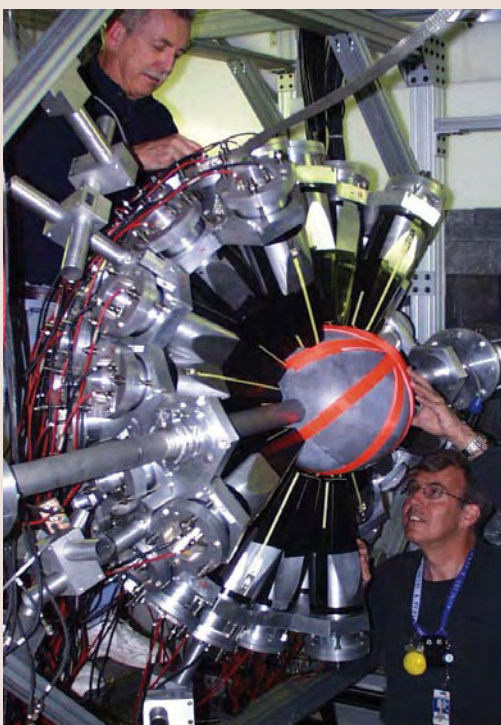
The environment created during a nuclear test is one of the most complex phenomena encountered in physics. Throughout the history of nuclear weapons development, the goal of the weapon designer has been to understand the underlying physical conditions that control device performance. Over the 50-year testing period, nearly all of the studied devices incorporated extensive diagnostic capabilities. Prompt diagnostics ranging from atmospheric fireball measurements through underground seismic monitoring to pinhole images have provided integral yields and modest spatial information.

However, the primary workhorse for determining detailed differential performance has been the study of nuclear reactions induced on a variety of “radchem” (radiochemistry) detector elements strategically loaded throughout the nuclear device. These radchem detectors undergo a series of nuclear

reactions that transform them from stable to radioactive species. Through the recovery of debris from the nuclear explosion, these radioactive elements produced during the test can be analyzed to give detailed information on the performance of the nuclear device. The colorful history of debris recovery ranges from a specially equipped shielded tank that sampled the Trinity test debris, through heroic fighter pilots sampling explosion clouds in early air bursts, on to the latest techniques in gamma-logged slant drilling to sample “puddle” regions after underground explosions.

For thermonuclear explosions, the nuclear weapons designers have great interest in the spatial distribution of the dominating 14-MeV neutrons generated through the nuclear

burning of deuterium and tritium to produce helium and neutrons. At these energies, the principal nuclear reaction occurring on the radchem detectors is $(n,2n)$. For example, if the stable isotope ^{169}Tm is used as a detector, the $(n,2n)$ reaction results in the production of ^{168}Tm , an unstable iso-



tope that has a 93-day half-life. By recovering the debris from a nuclear test, the amount of ^{168}Tm present can be determined and information garnered on the localized 14-MeV neutron fluence.

One complication is that the neutron fluence is often sufficiently high that multiple reactions become possible on a single isotope—i.e., the ^{168}Tm can undergo successive (n,2n) reactions to produce even lighter isotopes of thulium. A further complication is that the radchem data are “integral” measurements that are done long after the explosion. Although the designers’ greatest interest may be in the details of the thermonuclear fuel burn that is producing the 14-MeV neutrons, many of these “down scatter” and produce copious quantities of neutrons that approach energies that are thermalized in the local device environment. At these “bomb thermal” energies, the predominant nuclear reaction becomes neutron capture. This creates a very complex network of nuclear reactions that must be understood if the device performance is to be well characterized.

Following decades of nuclear reaction research, much is known about reactions that occur on stable species (such as ^{169}Tm in the above example), but very little is experimentally known for reactions on radioactive isotopes. However, it is precisely the reactions occurring on these species that perturb the isotopic production yields. To overcome this difficulty, the nuclear weapons design community has relied on theoretical predictions of reactions on off-stability species. Much effort has gone into this theoretical program, and great improvements have been realized.



However, even with these improvements, the pre-shot predictions of isotopic production often are not in good agreement with the experimentally observed values. To better reproduce the observations, it is frequently necessary to incorporate various parameter adjustments, or “knobs,” in the explosion design codes. Even though this “engineering” approach served the design community

well during the days of the testing program when additional device shots could be used to verify empirical predictions, the approach is much less acceptable in the current non-testing Stockpile Stewardship Program. Users of modern ASCII codes are attempting to perform realistic simulations of device explosions. It is, therefore, more critical that physical quantities, such as nuclear reaction cross sections, be put in the codes correctly and that the historic “knobs” be eliminated.

DANCE Neutron Cap-

ture Experiments

Though many of the nuclear reactions with the 14-MeV thermonuclear-generated neutrons can be accurately modeled ($\pm 10\%$), the same is not true for the neutron capture reactions on off-stability species where uncertainties of up to a factor of 10 are known. It is precisely for this reason that we have developed DANCE. The goal is to measure neutron capture reactions on off-stability species over neutron energies that are relevant to the nuclear device environment. This program requires a confluence of capabilities that occur only at LANL:

- radioisotope production using LANSCE,
- radiochemistry separation of highly radioactive materials,



A completed detector element consisting of a BaF_2 crystal wrapped with black plastic to keep out external light, a 3-in. photomultiplier tube, and an aluminum enclosure.

- isotopic enrichment of off-stability species,
- the world's most intense spallation neutron source—LANSCE/Lujan Center, and
- DANCE.

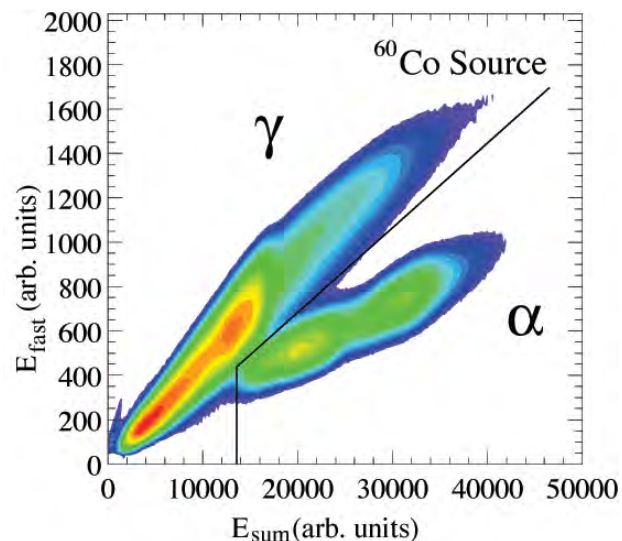
DANCE is a 4π detector that has 162 detector elements. It is made, similar to a soccer ball, of a series of pentagonal and hexagonal elements. The detector elements are 15 cm thick (sufficient to stop gamma rays of several mega-electron volts) and are made of BaF_2 , which has a very fast subnanosecond scintillation pulse that is detected by photomultipliers coupled to each detector crystal. For each detector element to subtend the same fraction of the detector sphere, four different crystal shapes are required—a regular pentagon, a regular hexagon, and two irregular “squashed” hexagons.

When DANCE is operated, it consists of 159 detectors. Three of the original detector elements are removed—two to permit ingress and egress of the neutron beam and one for insertion of a target ladder assembly. To minimize scattered neutrons reaching the detector elements while at the same time minimally perturbing emitted γ -rays, a ^6LiH ball surrounds the target/beam line assembly.

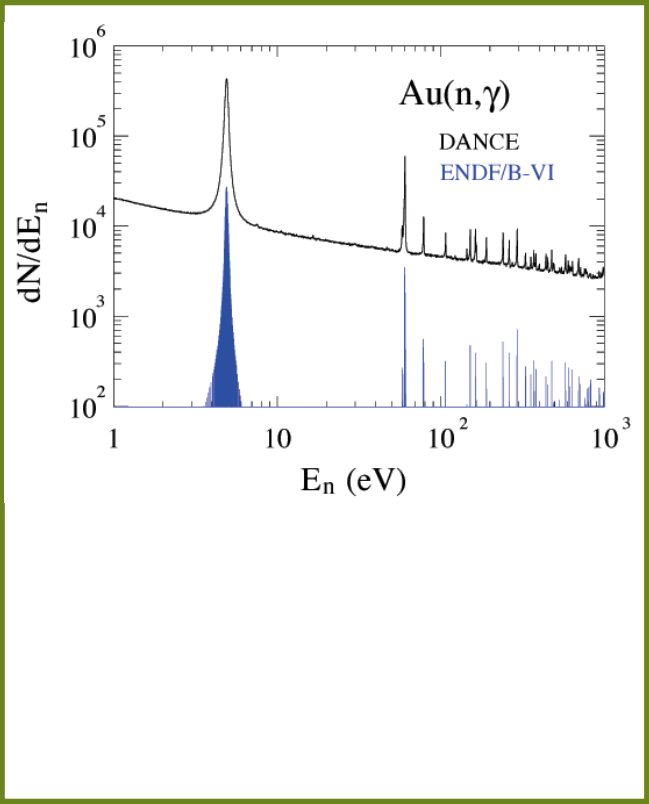
DANCE was installed on Flight Path 14 (FP-14)

of the Lujan Center during the summer of 2002. Commissioning runs were performed in the beam cycle period that ended in January 2003. During this period, only 141 of the detector elements had been received from the vendor. The data-acquisition system, consisting of two 500-MHz transient digitizers on each channel with associated control and logic systems, was also tested during this period. Detailed Monte Carlo simulations of expected signals were performed and compared with experimental results. Given the complexity of the system, these initial tests were very encouraging. Examples of results are shown in accompanying graphs for a gamma-ray calibration source, a stable gold target, and two uranium isotopes. The uranium isotope results represent the first high-resolution capture experiment on ^{224}U , and preliminary results from the neutron resonances in ^{236}U differ significantly from the evaluated nuclear data.

During the LANSCE maintenance period in the first half of 2003, the DANCE detector array has continued commissioning operations. The remain-



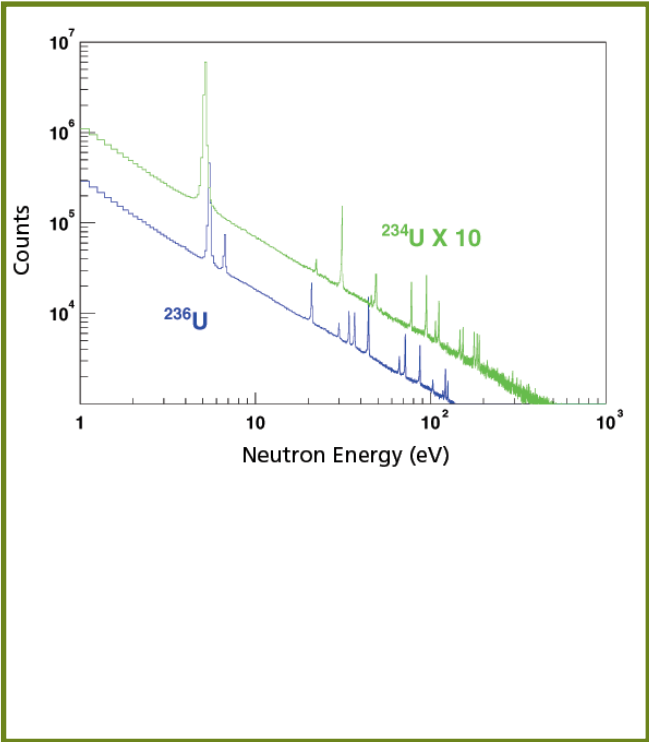
ing detector elements have been assembled and installed. The electronics and data acquisition systems have been improved and optimized based on knowledge gained during the 2002 test phase.



With the return of beam in the summer of 2003, DANCE is completing the commissioning phase and will shortly begin production operations. The emphasis will be on off-stable radchem detector elements and on the study of the capture cross sections on actinide elements of relevance to the weapons program. Initial radchem detector isotopes have been produced during 2002 by irradiations at the ILL reactor in Grenoble. The following table shows a preliminary time line of experiments for the Stockpile Stewardship Program. DANCE represents a new and unique capability for stockpile stewardship applications at LANL. With DANCE we will be able to anchor many of the uncertainties that have been associated with nuclear reactions, making a contribution

Stockpile Stewardship	
FY 2003	234-236, 238 U
FY 2004	234-236, 238 U, 237 Np, 169, 171 Tm
FY 2005	239, 240, 242 Pu, 170 Tm, 151, 153, 155 Eu
FY 2006	238, 241, Pu, 241, 242m, 243 Am, 173, 176 Lu

that is crucial for an improved understanding of device performance. This accomplishment will be an important step *science*-based stockpile stewardship.
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John Ullmann, 667-2517, ullmann@lanl.gov



Responsibility for Safety

Subcontractors, Deployed Workers, and Visitors

Ever wonder to whom you should go about your safety concerns at Los Alamos? If you're confused, you may not be alone.

When the Environment, Safety and Health Panel of the UC President's Council on the National Laboratories met at Los Alamos this summer, one panel member observed that integrated safety management (ISM) "sounds confusing, and if I can't figure it out, I'll bet there are lots of workers who don't understand who is responsible for the safety of the work."

His concern about ISM was based on information associated with recent safety-related occurrences at Los Alamos. He believed that the confusion about responsibility for safety is a result of the system that Los Alamos follows to ensure worker safety. That is, workers who belong to a "home" organization—that follows its safe work practices (SWP)—may be deployed and funded by another ("host") organization. This host organization may follow its own SWP and/or facility-specific requirements. This situation for safety responsibilities sometimes creates a reporting dilemma for a worker faced with a safety concern.

Lines of authority and responsibility may appear unclear and can become particularly complicated for subcontractors, deployed workers, and visitors. However, everyone at Los Alamos—UC employees, subcontractors, and visitors working here—is part of a safety chain-of-responsibility. Each worker, regardless of his or her position in that chain, has authorities and responsibilities for safety in the workplace. Although a worker may occasionally

perform supervisory or management functions, an individual can be

a member of only one safety line-management chain at a time, and a formal written agreement is required to transfer authorities and responsibilities from one organization to another.

How do you determine your place in a safety line-

Who ya
gonna call?

management chain? That depends on where you do your work.

If you are a worker, subcontractor, or visitor doing work at your home organization, report your safety concerns to your home organization supervisor. You are responsible for

- performing work safely, contributing to the safety of those around you, and minimizing adverse environmental effects;
- ensuring that the work has been authorized;
- ensuring that you are authorized to perform the work;
- ensuring that all applicable safety requirements are met;
- using lessons learned to make safety-related improvements to the work; and
- stopping work that you think may be imminently dangerous or that may have adverse consequences.

If you are deployed, report your safety concerns to your host organization supervisor. Responsibility for your safety may be transferred to a host organization if

- the transfer of responsibility is documented and acceptable to both the home and host organizations;
- the home organization retains salary and performance appraisal activities; and
- the host organization assumes safety responsibility for deployed as well as nondeployed workers.

How do you determine which safety line-management chain you should follow? That usually depends on funding. Most chains of responsibility for safety authorities and responsibilities follow funding. For example,

- subcontractors are hired through service contracts or task-oriented subcontracts and become part of the line-management chain of the contract-holding organization.
- guests, consultants, and other official visitors to Los Alamos have the same safety responsibilities as UC employees. Their Los Alamos host organizations are responsible for safety issues.
- deployed workers may have little contact with the home organization's safety line managers for long periods, or a line manager may not be familiar with the hazards or controls of the deployed person's new work environment. In those cases, responsibilities and authorities for the deployed workers' safety may be transferred to the employers' host organizations.

Identifying your safety line-management chain is not difficult: remember how your work is funded, and follow that same chain. Report a potential safety issue as you would any other work-related issue—to your supervisor (the person for whom you do work), who in turn will report that issue or concern to his or her manager, and so on through the line-management chain of responsibility. When you think about the funding, responsibility for workplace safety becomes more clear, even for subcontractors and deployed and visiting workers.



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Security Help Desk

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The Security Help Desk has answered questions and provided information to more than 13,000 callers since June 2000. The Help Desk responds to safeguards and security inquiries involving program management, protection program operations, materials control and accountability, information security, and personnel security.

- **One-Stop Shopping:** The most significant benefit is the creation of a one-stop shop capable of handling the majority of questions and problems. Help Desk personnel work closely with security subject matter experts (SMEs) to ensure that customers receive correct answers and that the questions and their answers are maintained in a database to ensure that consistent answers are given when similar questions are asked later.
- **Problem Solving:** Many of the unique problems require a great amount of SME attention. The Help Desk works with SMEs to determine the root cause of problems and to assist in their resolution. Data are provided to the Safeguards and Security Training Team, which evaluates the data and determines if additional training should be developed. The Help Desk is often contacted concerning an event or situation that falls into the official "incident of security concern" category; these calls are forwarded to security personnel for appropriate action.
- **Information Sharing:** In many cases, customers want to be pointed to online information and resources. A key function of the Help Desk is to know where the guidance is located and to direct the customer to that information.
- **Lessons Learned:** A great institutional benefit is the ability to collect vast amounts of data concerning common security problems and to examine these data for trends.

When significant trends are identified, Help Desk personnel and SMEs analyze the data and determine actions to resolve current issues or prevent future incidents from occurring.

Marcene Roybal, 665-7782, marcene@lanl.gov

- design, and life-cycle process design to prevent the generation of wastes.
- Reduced number of <90-day storage areas and better training for line-division compliance with RCRA.
- Accelerated cleanup actions through DOE's Performance Management Plan.

- Increased services to the weapons complex and others for off-site source recovery and disposition (e.g., to the WIPP).

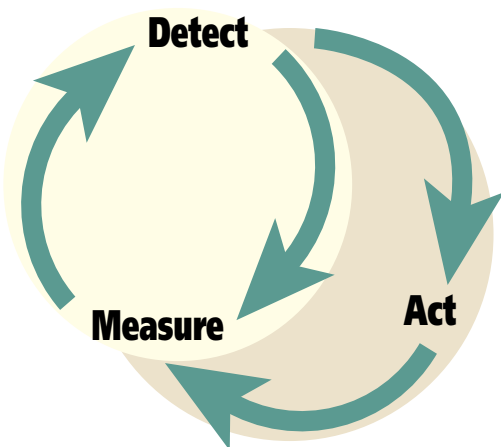
This column begins a series of environmental articles that will address partnerships between RRES Division and weapons engineering and science operations,

such as

- off-site source recovery,
- the Risk Communication/Assessment Initiative (Colorado State University is leading this effort),
- remediation services, and
- transuranic and mixed-waste disposition.

RRES Division is here to help you improve your construction, operations, and decontamination and decommissioning activities. We provide alternative schemes to save you money, eliminate compliance headaches, and disencumber facilities and sites from legacy contamination. Together, we can make real strides toward several of our recently defined Los Alamos strategic goals, including

- Designing and engineering manufacturable and certifiable replacement nuclear weapons without new nuclear testing.
- Improving the efficiency with which we achieve regulatory compliance and manage risk to support operational excellence.
- Using LANL expertise and capability to solve national problems in energy security. 🌟



Compliance Conundrum

- Always defensive
- Actions not focused on reducing risks
- Media-specific activities
- Difficult to prioritize budgets and work

The compliance conundrum for the Environmental Surveillance Program has evolved from protection to chasing contaminants.



Risk Management

- Offensive position
- Actions focused on risk reduction
- Site-wide holistic approach to risk reduction
- Risk-based budgets and work prioritization

A risk-reduction approach combines measurement, prioritization, and evaluation to manage an acceptable level of risk.

Continued on page 24

The Risk Reduction and Environmental Stewardship Division was formed in April 2002 from four predecessor organizations to be the “one-stop shop” for environmental programs and mission support. RRES Division was chartered to be the institutional instrument for continual reduction of operational risks to the public and our host ecosystems.

The RRES Division mission is

- to reduce the risk of current and historic LANL activities to the public, workers, and the environment through natural and cultural resource protection, pollution prevention, deployment of risk/cost-effective measures for transuranic waste disposition, and environmental remediation.
- to be stewards of the LANL reservation through risk communication, strategic monitoring and surveillance, and integrated natural and cultural resource management.
- to ensure LANL’s sustainability by

continually improving our support of the Laboratory’s mission, our social responsibility in northern New Mexico, and environmental protection of the Pajarito Plateau.

The RRES vision commits to the service—not only of LANL but to LANL—to ensure long-term economic development, education, and environmental quality of the Pajarito Plateau:

Mission-driven, market-sensitive, community-integrated risk reduction and environmental stewardship activities with a bias for action resulting in LANL sustainability.

Organizational Acronyms and Abbreviations

AWE	Atomic Weapons Establishment (UK)
C-PCS	Physical Chemistry and Applied Spectroscopy Group
DANCE	Detector for Advanced Neutron Capture Experiments Facility
DARHT	Dual-Axis Radiographic Hydrotest Facility
DoD	US Department of Defense
DOE	US Department of Energy
DX	Dynamic Experimentation Division
ILL	Institut Laue-Langevin
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LANSCE-1	Accelerator Physics and Engineering Group
LANSCE-3	Neutron and Nuclear Science Group
LBNL	Lawrence Berkeley National Laboratory
LLNL	Lawrence Livermore National Laboratory
MST-8	Structure/Property Relations Group
NNSA	National Nuclear Security Administration
P-23	Neutron Science and Technology Group
P-25	Subatomic Physics Group
RRES	Risk Reduction and Environmental Stewardship Division
UC	University of California
WIPP	Waste Isolation Pilot Plant
WNR	Weapons Neutron Research Facility

BACKWARD GLANCE

Gamow's Shields

In 1949, medieval-looking shields mysteriously appeared on the office doors of several T-Division staff members. These shields were divided into panels that bore personal, scientific, and technical artwork related to the recipient. After a brief investigation, the shields were traced to a visiting consultant, George A. Gamow.



Robert Richtmyer, T-Division leader from 1945–1946. Richtmyer was carrying punch card computations to new levels of sophistication (lower-left quarter). The lower-right quarter refers to his mathematical studies of Cepheid variables.

George Gamow, along with his wife, fled the Soviet Union in 1933. In 1934, he accepted a professorship in the physics department at George Washington University. A year later, Edward Teller joined that department; together, Gamow and Teller published a number of papers on the pair theory of nuclear forces, selective thermonuclear reactions, and the origin of the great nebulae. Their first doctoral student, Charles Critchfield, later became a wartime staff member at



Carson Mark, T-Division leader in 1946. The chain reaction in the lower-left quarter contains the names of the members of the division. The lower-right quarter refers to Mark's large family and numerous cats.

Los Alamos. Critchfield once commented that his graduate studies were conducted in German, since it was the only language thoroughly understood by all three.

Gamow, who became a naturalized American citizen, did not get involved in defense work during World War II. Rather, he turned his attention to stellar evolution and focused on defining what happens to stars whose central regions are depleted of hydrogen. In part because of his work in this field, T-Division made him a consultant to the growing Super program. The shields, of which only four survive in photographs, began appearing shortly after his arrival.

James Tuck, rescued his shield as well as those of Carson Mark, Robert Richtmyer, and Edward Teller before the old T-Division Building fell to

the onslaught of a bulldozer. After having the shields reproduced, Tuck returned the shields to their owners. It is not known if any survive. ✨

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James Tuck, T-Division leader in charge of controlled thermonuclear research in 1951. The “perhaps” and “pinch” refer to the “Perhapsatron” toroidal pinch device. The lens in the lower-right quarter refers to the explosive lens used in the first fission bomb.



Edward Teller. Superman in the upper-left quarter refers to Teller's theoretical studies of devices involving thermonuclear burning—code-named “Super” at Los Alamos in the 1940s. The inscription refers to a blocked door in Teller's office, through which visitors were apt to try to enter.